Postnatal behavioral and physiological responses of piglets from gilts housed individually or in groups during gestation

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ABSTRACT: Gestational housing of sows remains a controversial issue that may affect the well-being of both sows and piglets. Therefore, 2 types of gestational housing were used to evaluate the stress imposed on pregnant gilts by each system and the effects on the offspring by comparing production, physiology, and behavioral measures of the piglets. Forty-eight Landrace × Yorkshire gilts were randomly assigned to groups (G) of 4 per pen (n = 8 pens; 3.9 m × 2.4 m) or to individual stalls (S; n = 16 stalls; 2.21 m × 0.61 m). Gilts were moved into individual farrowing crates 5 d before the expected farrowing date. Piglets were weighed at birth, d 14, and d 35. Two barrows from each litter were weaned at d 14 (early weaning) and housed together in pens. Maintenance behaviors (head in feeder, drinking, lying, eating mash) were videotaped and observed for the first 3 d after weaning using a 10-min interval scan sampling. Belly nosing and play/fight interactions were recorded from video observations for 3 d postweaning. An isolation test (30-min duration) was performed on one piglet from each pen of barrows on d 35. Time spent lying, the number of jumps against test box walls, and grunts and squeals were recorded in real time. Salivary cortisol was collected at 30-min intervals from baseline, and 0, 30, 60, and 90 min posttest. Jugular blood was collected from 2 barrows from each litter on d 1, 7, 14, 17, 21, and 28. Plasma TNF-α was analyzed by ELISA, and haptoglobin, α_1-acid glycoprotein, and immunoglobulin G were analyzed by radial immunodiffusion. More piglets from the S treatment needed to be fed a liquid feed at weaning and drank more frequently on d 2 postweaning ($P < 0.05$). Additionally, by d 35 piglets from S gilts had a lighter BW (10.3 kg) than G piglets (12.8 kg; $P < 0.01$). Piglets from S gilts also grunted more during the 30-min isolation test (number of grunts = 356) than G piglets (number of grunts = 138; $P < 0.01$). Salivary cortisol and immune measures were not different. These data show some behavioral and production differences between piglets from individually stalled gilts and group-housed gilts. Therefore, there may be production advantages to housing first parity gilts in groups.

Key words: acute phase response, behavior, isolation test, prenatal stress, swine gestational housing

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INTRODUCTION

The use of gestation stalls in pig production continues to be a public concern. This study was designed to test the effects of small group housing compared with gestation stalls on the offspring of pregnant gilts. The restrictive nature of stall housing may create physical and psychological stress on the pregnant sow. If that is true, stress on sows caused by housing conditions may also be an indirect source of prenatal stress on piglets.

Research with stressed pregnant mice and rats is contradictory. They can have offspring either more adept at coping with stress (Clarke et al., 1994; Lambert et al., 1995; Batuev et al., 1996) or less adept at coping with stress (Clarke and Schneider, 1997; Vallee et al., 1997; Weinstock, 1997). The dichotomy may be created by differences in species physiology, including placental barrier and hypothalamic-pituitary-adrenal development, or time and type of stressor given.

Physiological indicators are also used to help indicate stress responses. In pigs and cattle, peripheral blood concentrations of acute phase proteins can provide an objective measure of the health status of an animal and are increasingly being used as markers of animal health and welfare. Changes in these plasma proteins are observed within hours or days after the onset of infection or inflammation, although many acute phase changes also indicate persistent disease and are exacerbated by stress (Dinarello, 1984).

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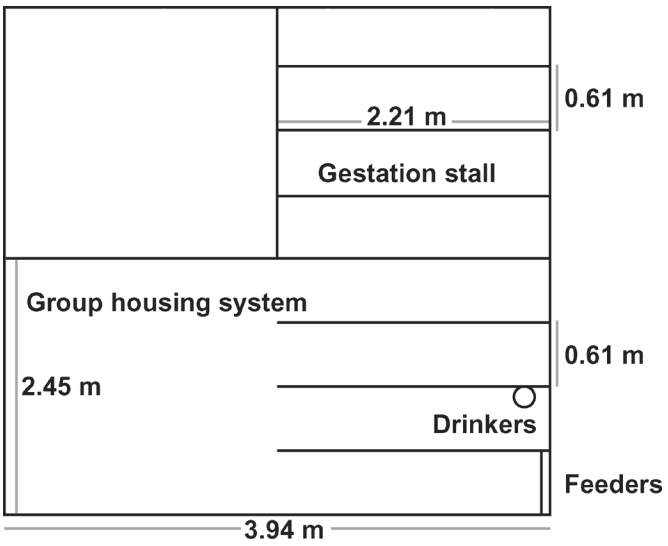

Figure 1. Gestation stall (standard industry size) and group housing (4 gilts per pen) systems used in the present experiment.

By extrapolating the data from rodents, it is possible to hypothesize that exposure of a pregnant sow to stress may have negative effects on the piglet's ability to cope with stressful situations later in life, such as castration, tail docking, weaning, and mixing. Our objective was to determine if group gestational housing for gilts resulted in piglets with physiological or behavioral changes compared with piglets of gilts that were housed in individual stalls.

MATERIALS AND METHODS

Animals and Housing

Landrace × Yorkshire gilts (n = 48) were bred and housed at the Purdue University Animal Sciences Research and Education Center for the initial experiment. All animals were cared for by the Purdue Swine Unit animal care staff according to the research protocol approved by the Purdue Animal Care and Use Committee. Each gilt was assigned a housing treatment (Figure 1) of either a group (**G**) of 4 (3.94 × 2.45 m with 4 individual feeding stalls) or an individual stall (**S**; 2.21 × 0.61 m). Bred gilts were moved into their treatment housing 7 d after breeding. Before that, all gilts had been group-housed. Five groups had 1 gilt that was removed from the study for medical reasons or was not pregnant. One group had 2 gilts that were not pregnant, and 2 in the stall housing were not pregnant. Gilts that were not pregnant were left in the group.

On d 111 of gestation, pregnant gilts were moved into a farrowing barn into standard farrowing crates (0.61 × 2.13 m). One heat lamp (250W) and one mat (30.5 × 121.9 cm) were provided for the piglets. A total of 39 litters were born, and 38 of those litters resulted in weaned piglets. Pen was the experimental unit for this study, resulting in 8 pens of group-housed gilts and 16 pens of stall-housed gilts.

All piglets received standard processing (ear notches, tail docking, castration, and iron supplement by i.m. injection) on d 3 of age after birth, from the same Purdue Swine Unit staff member. Two barrows closest to the average male birth weight (1.73 kg) were selected from each litter to represent the sow's treatment. Only barrows were used to remove sex-based immune and weight differences. On d 14, these piglets were weaned and moved into 1 of 2 identical climate-controlled rooms. Each pair of related piglets was put into pens (71.12 cm tall × 76.2 cm long × 81.28 cm wide) with water nipples (adjusted for the piglets' heights) and 4 feeders (20.32 cm wide). Weaning rooms were temperature-controlled at 28.9°C and then reduced to 27.8°C at 1 wk postweaning. Piglets were kept on a timed 12-h light cycle. Piglets received 0.68 kg of a nursery diet (blood plasma protein pellet) on the first day of weaning and 1.36 kg per piglet for several days thereafter. The transition diet was then given at 2.72 kg per piglet for 3 d. The grower diet was administered ad libitum thereafter. To encourage eating of solid feed, the staff gave dampened starter pellets (mash) to piglets that had not eaten within 48 h of weaning.

Sampling Procedures

Blood samples (3-mL) were drawn via jugular venipuncture from piglets that were restrained on their backs in a V-trough. Samples were taken within 48 h after birth and on d 7, 14, 17, 21, and 28 after birth. Samples were collected within 3 min of restraint. Blood samples were collected into heparinized tubes and kept on ice until centrifuged at 650 × *g* for 15 min. Plasma was then stored in Nunc CryoTubes vials (Nagle Nunc International, Denmark) at –80°C pending determinations of TNF-α, immunoglobulin G (**IgG**), haptoglobin (**HP**), and α_1-acid glycoprotein concentrations.

Piglets were subjected to a 30-min isolation test on d 35 of age. Day 35 was selected because it provided time for recovery from the stress of early weaning. Saliva samples were collected for cortisol analysis at baseline, after 30 min in the isolation box, and at 30, 60, and 90 min after returning to their home pen. Cotton rolls (3.7 cm) tied to fishing line were used to collect saliva from piglets' mouths. Piglets were allowed to chew on the cotton for up to 2 min. The cotton rolls were put in 3-mL syringe sleeves that were stored in 15-mL conical tubes. Samples were kept on ice for transport to the laboratory and stored at –80°C until assayed. Piglets were weighed at birth and on d 14 and 35.

Physiological Analysis

Cortisol. Salivary concentrations of cortisol were quantified using a Coat-A-Count Cortisol kit (Diagnostic Product Corporation, Los Angeles, CA). This radioimmunoassay kit was designed for the quantitative

measurement of cortisol in serum, urine, heparinized plasma, and saliva. Unknown concentrations were compared against the cortisol kit standard and were expressed as μg/dL of cortisol. This value was then converted and expressed as ng/mL of cortisol. Duplicates of salivary samples were quantified in 200 μL aliquots in 1 of 5 assays (interassay CV was 5.1%, and intraassay CV was 5.7%). The use of the cortisol and ACTH kits for porcine samples has been validated (Daniel et al., 1999).

Acute Phase Proteins and IgG. Haptoglobin and α_x-acid glycoprotein (**AGP**) were selected as acute phase proteins to indicate immune or physiological status. Haptoglobin is a sensitive indicator of infections and pathological lesions (Eckersall et al., 1996; Wimmers et al., 2004). Early reports showed that AGP and HP increased during inflammation (Asai et al., 1999; Heegaard et al., 1998; Itoh et al., 1993). Haptoglobin and AGP concentrations (μg/mL) were determined by radial immunodiffusion (**RID**) using a kit (Saikin Kagaku Institute Co., LTD., Sedai, Japan) specific for porcine Hp and AGP. The HP assay intraassay CV was < 20% and interassay CV was <10%. Inter- and intraassay CV for AGP were below 10%. Concentrations of plasma IgG were determined using pig IgG VET-RID Plates (Bethyl Laboratories, Inc., Montgomery, TX). The RID analysis was based on an antigen-antibody reaction occurring in a support medium (agarose gel) and was visible as an opaque precipitin ring. The IgG concentrations of unknown samples were determined using linear regression of semilog plots of the standards provided in the kit. The use of haptoglobin and acid glycoprotein RID kits has been validated (Daniel et al., 1999). The lgG RID used in this study has been adequately validated by VMRD (http://www.vmrd.com/company/QualityStandards.htm).

Tumor Necrosis Factor-Alpha. Tumor necrosis factor-alpha (**TNF-α**) concentrations were determined using Porcine TNF-α colorimetric ELISA kit (Pierce Endogen,Woburn, MA). This kit was a sandwich ELISA that utilizes anti-human TNF-α antibodies that recognized porcine TNF-α. The enzyme-substrate reaction generated a colorimetric signal that and the absorbance was determined by subtracting the absorbance at 450 nm minus the absorbance at 550 nm. Linear regression was used to determine the TNF-α in the sample. For the TNF-α assay, the intraassay CV was 10.4%, and the interassay CV was less than 10%.

Behavior

Behaviors were recorded using Panasonic BP330 black and white and WVCL350 color cameras with 4.5 mm lenses (Mipitas, CA), placed at 2.1 m above the piglet's head. Panasonic AG6730 VCRs and Panasonic WJ416 quad units (Mipitas, CA) were utilized to record behaviors on VHS tapes. Maintenance behaviors (head in feeder, drinking, lying, eating mash; Table 1) were observed during the first 3 d days after weaning via 10-min instantaneous scan samples (Noldus Observer; Wagegingen, Norway) of video recorded one frame per 1.2 s (72-h mode). Belly nosing and play/fight (not distinguished) were also observed during the first 3 d following weaning in 72-h mode. Behaviors were defined before observations were made (Table 1).

An isolation box (floor area = 68.23 cm^2; height = 7.21 cm), constructed of interlocking plastic panels that slid into 4 corner pieces, was used to administer an isolation test on d 35. The 4 plastic corner pieces were connected to steel pipes for weight stability (Figure 2). A Panasonic BL90A camera with a Panasonic microphone was mounted 1.72 m above the box to record behaviors and vocalizations of a randomly chosen piglet from each weaning pen. The piglet was carried from the pen to a room between the identical physiology rooms (2 to 10 m for each room), where the piglet was placed into the isolation box. The total time of carrying and transfer to the box was less than 2 min. After placing the piglet into the isolation box, the 2 examiners immediately left the room and returned 30-min later to collect saliva for cortisol analysis. Once saliva was collected, the piglet was immediately returned to its pen and pen mate. The behaviors jumping, lying, active (not lying or jumping; Table 1), grunting, and squealing were recorded by videotaping continuously for the entire 30-min isolation test and later analyzed using the Noldus Observer software. Each piglet served as its own control. In this test, separation stress was an integral part of isolation stress.

Statistical Analysis

Piglets were assigned to their mother's treatment (group-housed or individually stalled), and the sow's pen remained the experimental unit. Data were analyzed as a randomized complete block design with repeated measures over time using Mixed Models of SAS (SAS Institute, Inc., Cary, NC) after testing for normality and transforming the data when necessary (Littell et al., 1998). The model included terms for the fixed effects of treatment, time, and treatment × time interactions. Random effects were pen within treatment, sow within pen × treatment, and piglet within treatment × pen × sow. Treatment effects were deemed significant at $P < 0.05$, and a trend for a treatment effect was noted when $P < 0.10$. Data that were log transformed for analysis were back-transformed for presentation. The percentage of piglets requiring mash was analyzed by χ^2 analysis using Fisher's exact test in SAS.

RESULTS

Physiological Data

Tumor Necrosis Factor-Alpha. Tumor necrosis factor-alpha concentrations were not different between piglets from G gilts and S gilts. Tumor necrosis factor-α plasma peak concentrations averaged 78.9 ± 13.3 pg/mL (Figure 3). Baseline concentrations were 47.8 ± 13.2

Table 1. Behavioral definitions

Behavior	Definition
Active	Any moment animal is standing or locomotive.
Belly nosing	Repeated rhythmic up-and-down massage movements with the snout on another piglet's belly. Described by Fraser (1978).
Drinking	Voluntary oral ingestion of liquids. Definition from Hurnik et al. (1995). Here, we include any time the piglet manipulated the water nipple with its snout.
Eating mash	Ingestion of wet phase 1 diet offered to newly weaned piglets that had not eaten feed by d 3 after weaning.
Grunt	The most common vocalization of mature pigs produced as a sound of low to medium amplitude. Grunting may consist of single grunts, but more commonly occurs as a series of repeated sounds produced with the mouth closed or only slightly open. The pitch of grunts is usually between 1 and 4 kHz. According to the duration of individual sounds, grunts can be subdivided into short, medium, or long. Short grunts (0.1 to 0.2 s) appear to be a sign of mild excitement and often are produced when a pig is frustrated or greeting another individual. Mid-length grunts (0.2 to 0.4 s) are often produced during interactions with familiar peers and also during the milk ejection phase of a normal nursing cycle of a sow. Long grunts (0.4 to 1.2 s) are produced in response to tactile stimulation such as occurs during courtship and the nursing cycle (particularly the nosing and slow suckling phases). Definitions from Hurnik et al. (1995).
Head in feeder	The animal put its entire head into the feeder. This did not assume that the animal was ingesting feed.
Head knocks and bites	Head knocks represented a rapid thrust upwards or sideways with the head or snout (Jensen, 1980) and directed toward another piglet. Bites were defined as the piglet directing an aggressive bite toward another piglet.
Jump	Springing from the ground or surface with the propulsive force being derived primarily from the action of the legs. Definition from Hurnik et al. (1995). Here it was seen by piglets in isolation and was directed against the isolation box wall.
Lying	Maintaining a recumbent position. Definition from Hurnik et al. (1995).
Squeal	An extended sound (0.5 to 2.0 s) of both high amplitude and high frequency produced with an open mouth, indicative of a high level of excitement, fear, or pain. Squeals are more frequent in young animals. Definition from Hurnik et al. (1995).

Figure 2. Piglet in the isolation test box (floor area = 68.23 cm^2; height = 7.21 cm).

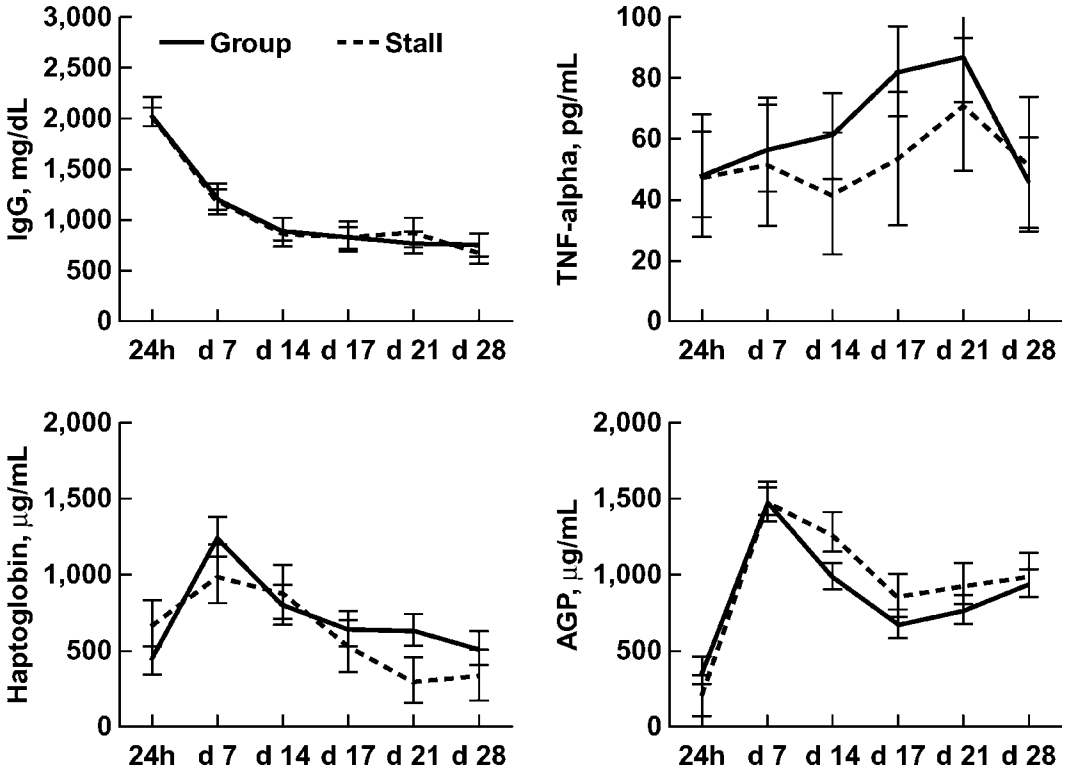

Figure 3. Means ± SEM of plasma tumor necrosis-α (TNF), α_1-acid glycoprotein (AGP), haptoglobin (HP), and immunoglobulin G (IgG) concentrations of piglets from gilts housed in groups and gilts housed in stalls during gestation. There was a time effect ($P < 0.01$) for AGP, HP, and IgG for both treatments. Weaning occurred on d 14. Log transformations were used for data analysis of TNF, AGP, and IgG, and the data are presented as back-transformed means (n = 11 pens/treatment).

pg/mL. Time effect and treatment × time effect also were not detected.

Acute Phase Proteins. A time effect, but not a treatment effect, was significant for both AGP and HP ($P < 0.01$; Figure 3). The high concentrations of AGP within 24 h of birth (1482 ± 90.45 ug/mL) are similar to data reported for specific pathogen-free and conventional newborns (Itoh et al., 1993). Adult levels, established at 500 μg/mL (Itoh et al., 1993), were not reached by d 28. Plasma HP concentrations averaged 556 ± 88.6 μg/mL within 24 h of birth, peaked at d 7 (1125 ± 119.45 μg/mL), and returned to normal adult levels by d 28.

Immunoglobulin G. Neither a treatment effect nor a time × treatment interaction occurred in plasma IgG levels (Figure 3). However, concentrations decreased significantly over time for both treatments ($P < 0.01$). Plasma IgG concentrations were high within 24 h of birth (2033 ± 89.1 mg/dL), decreased by weaning (879.8 ± 83.7 mg/dL), and stabilized at 729.2 ± 89.2 mg /dL by d 28.

Cortisol. Treatment did not affect cortisol for piglets from S gilts and G gilts during or following isolation testing (Figure 4). However, both treatments show a time effect ($P < 0.01$) where concentrations peaked immediately following the test and returned to baseline over the next 90 min.

Behavioral Data

Maintenance behaviors recorded during the first 3 d after weaning (d 14 to 17) included head in the feeder (duration and feeding frequency), drinking (latency and frequency), lying (duration and latency), and eating mash (Figure 5). The duration and latency to eat of piglets from G gilts were similar to those of piglets from S gilts. Piglets from S gilts drank more frequently ($P < 0.05$, Figure 5) than did piglets from G gilts on d 2 but were not different on d 1 or 3. Piglets that did not eat dry feed within 48 h of weaning were given a pan of dampened feed (mash). More piglets from S gilts needed to be given mash than piglets from G gilts ($P < 0.05$). It is important to note that piglets from G gilts did not have to be offered mash. All of the piglets from the G gilts were able to adapt to dry feed within 48 h. There were no differences between treatments in the frequency of lying or the latency to lie.

Differences between treatments were not observed for duration of belly nosing or play/fighting, nor were treatment effects found in the frequency of belly nosing or play/fighting.

Behaviors recorded during isolation testing included number of jumps against test box walls, time spent lying and being active, and the number of squeals and

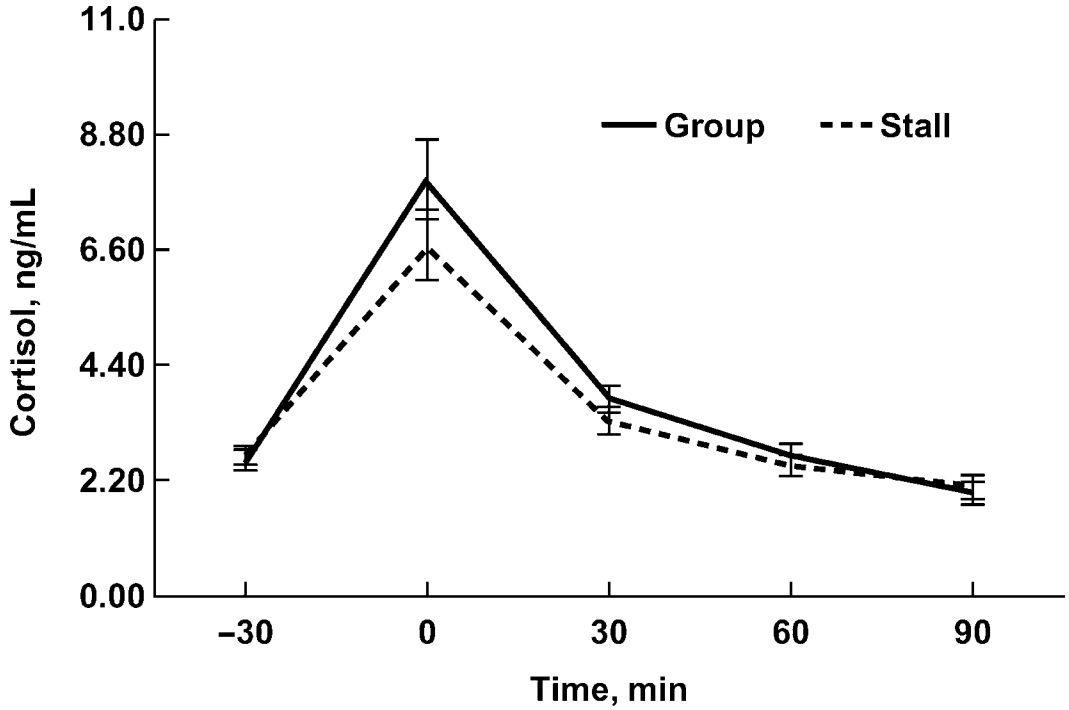

Figure 4. Salivary cortisol concentrations (means ± SEM) of 35-d-old piglets subjected to isolation testing (n = 11 pens/treatment).

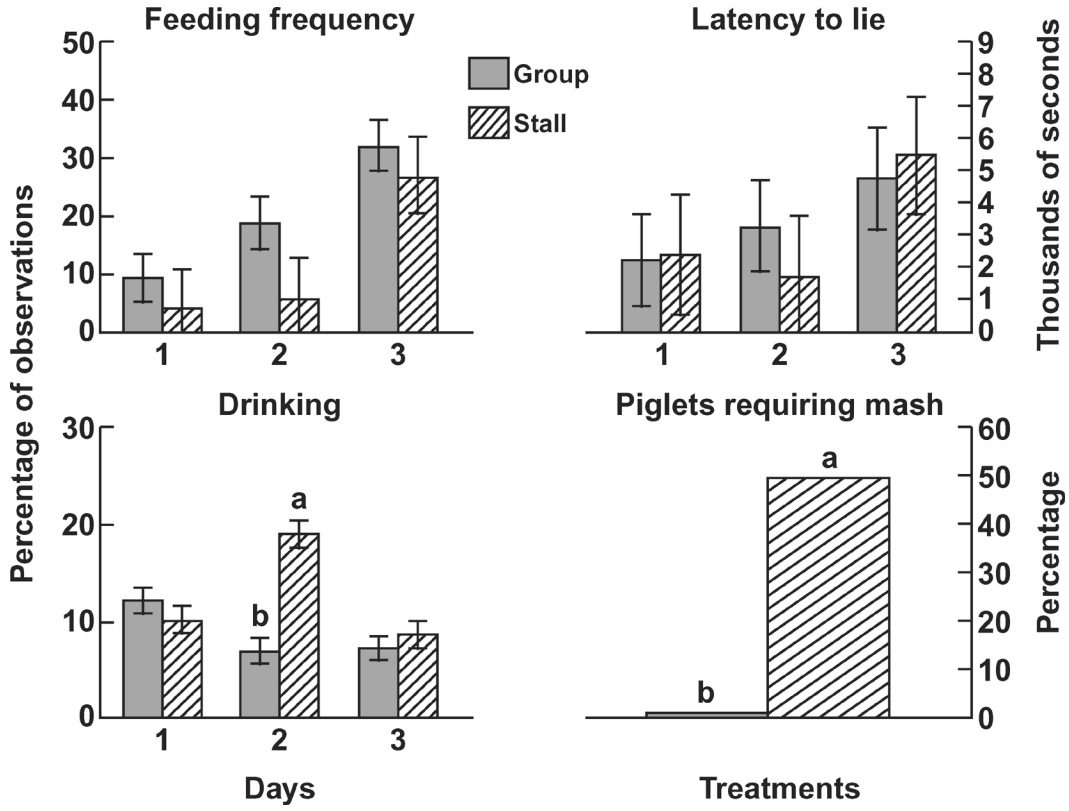

Figure 5. Means ± SEM for feeding frequency (time effect, $P < 0.01$), latency to lie, drinking frequency (time effect, $P < 0.01$; treatment effect on d 2, $P < 0.05$), and needing to be fed mash ($P < 0.05$) of piglets from group- or stall-housed gilts. Log transformations were used to analyze latency to lie and square root transformations were used to analyze feeding frequency and drinking frequency. Means were back-transformed for presentation (n = 11 pens/treatment). [a,b]Within a variable, means within a day with differing superscripts differ ($P < 0.05$).

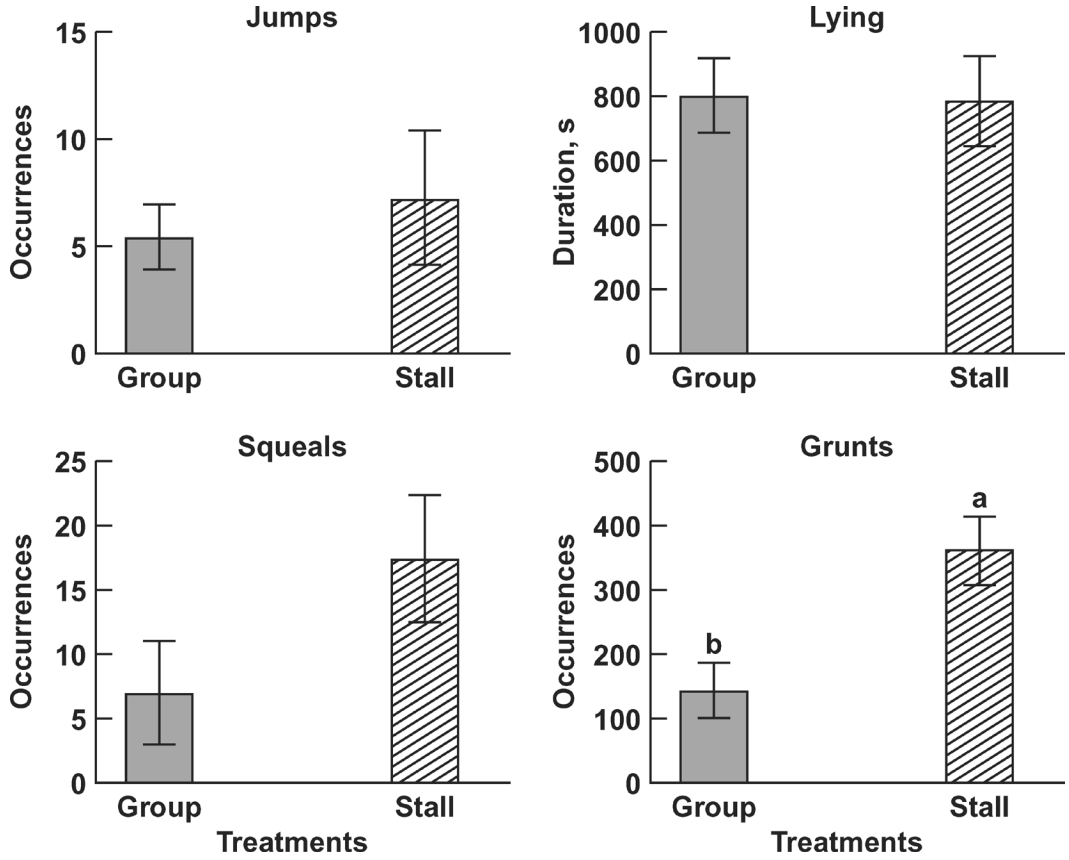

Figure 6. Number of jumps against the isolation test box, duration spent lying, and number of squeals and grunts by piglets born to group and stall-housed gilts during isolation testing (30 min; n = 11 piglets/treatment0. [a,b]Within a variable, means ± SEM with differing superscripts differ ($P < 0.05$).

grunts (Table 1). Treatment was not different for the number of times a piglet jumped against the test box walls. Time spent being active and lying also did not differ between treatments. However, piglets from S gilts grunted (356 vs. 138; $P < 0.01$) more frequently than piglets from G gilts (Figure 6), but squealing (17 vs. 7) was not different.

Production Data

Weaning weights were similar, averaging 4.1 kg for piglets from S gilts and 4.9 kg for piglets from G gilts. However, by d 35, treatment differences were evident in BW. Piglets from S gilts (10.3 kg) weighed less compared with piglets from G gilts (12.8 kg; $P = 0.01$; Figure 7). Feeding behavior corresponded with the BW data, where piglets from G gilts ate unassisted by 48 h after weaning ($P = 0.05$) and weighed more by d 35.

DISCUSSION

The gilts' behaviors have been previously reported for this study (Harris et al., 2001). Gilts housed in stalls during gestation performed stereotypic behaviors more frequently than gilts housed in groups. However, immune (Sorrells et al., 2001) and production data (Harris et al., 2001) of the gilts did not differ significantly between the treatments. Their piglets expressed few phys-

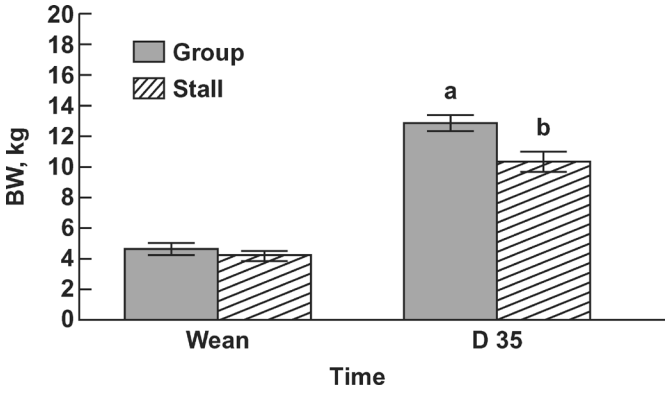

Figure 7. Weight (means ± SEM) of piglets born to gilts housed in groups or stalls during gestation at weaning on d 14 and at d 35 ($P < 0.01$; n = 11 pens/treatment). [a,b]For d 35, means with differing superscripts differ ($P < 0.05$).

iological differences in this study, but piglet production and behavioral data showed some differences between treatments. In contrast, Tuchscherer et al. (2002) showed that piglet serum IgG concentrations were lowered by prenatal stress of gilts (snaring for 5 min/d for 4 wk). Our IgG concentrations were about one-half of the IgG concentrations reported by Tuchscherer et al. (2002). This could be because of the difference of the specificity of the antibodies in the assays and the difference between a RID and ELISA for measurement.

Tuchscherer et al. (2002) also showed decreased lymphocyte blastogenesis of the piglets from prenatally stressed gilts that lasted through d 7 for concanavalin A and pokeweed mitogen and through d 1 and 35 for lipopolysaccharide. An ACTH challenge test showed less response by piglets from prenatally stressed gilts, and they had lower thymus:BW on d 1 and 35. These data all point to a suppressive effect of prenatal stressors on the piglet lymphocyte functions up to 35 d after birth.

The remaining measures of our study (TNF-α concentrations, plasma HP, and α_1-acid glycoprotein) were part of an acute phase response of innate immunity. Haptoglobin, for example, has been used to identify both clinical and subclinical diseases in animals and for objectively monitoring antibiotic therapy in experimentally infected animals (Eurell et al., 1992). Glucocorticoids play a role as inducers in the acute phase process (Neuhaus et al., 1966; Baumann et al., 1986) and act synergistically with cytokines to mediate changes in AGP gene expression (Stone and Maurer, 1987; Richards et al., 1992). However, these measures were not different between the treatments in our study. Tumor necrosis factor-alpha began with an elevated baseline, which may be in response to a pathogen in the housing. The herd is a porcine reproductive and respiratory syndrome stable herd and was not exhibiting symptoms during the study. Taken together, it appears that the adaptive immune system but not the innate immune system of the offspring may be more susceptible to suppression by maternal stressors. However, the type of stressors may play different roles on immune function modulation. This accentuates the need to test different types of stressors rather than to generalize across stressors.

More piglets from S gilts than G gilts were not eating within the first 2 d postwean, and therefore had to be offered mash, explaining the treatment differences in frequency of eating mash. These data suggest that piglets from S gilts had a more difficult time adjusting to solid food and thus weighed an average of 2.3 kg less than piglets from G gilts after weaning. The piglets that needed to be fed mash were drinking more on d 2, which might be because they were searching for liquid feed rather than consuming the dry feed.

Activation of the hypothalamic-pituitary-adrenal axis in response to stress seems to influence fetal development (Lay et al., 1997). The mechanisms underlying the effects of prenatal stress have not been established, but high levels of glucocorticoids secreted in response to stress make maternal glucocorticoids an obvious candidate programming factor in this paradigm (Welberg et al., 2000). In rats, prenatal exposure to the synthetic glucocorticoid dexamethasone reduces birth weight, affects brain development (Slotkin et al., 1993), and programs hypertension and hyperglycemia in adult offspring (Benediktsson et al., 1993; Nyirenda et al., 1998). However, we did not detect an effect of either housing system on the plasma cortisol in these piglets. Similarly, isolation stress of ewes did not affect lamb cortisol responses (Roussel et al., 2004), nor did piglets of sows subjected to restraint stress have altered cortisol responses (Tuchscherer et al., 2002).

Coping with stress has been thought to occur when subjects show increased mobility in an open field test, more entries and time spent on open arms in an elevated plus maze (Andersen et al., 2000), reduced reactions to electric shock (Haltmeyer et al., 1966), and increased contact with humans in human approach tests (Hemsworth and Barnett, 1992).

Behaviors and physiological parameters explored during these tests include those typical of the stress response, such as increased heart rate and respiration, locomotion, and vocalizations. Piglets from S gilts vocalized, with grunts, more frequently in isolation than piglets from G gilts, suggesting that piglets from S gilts were more affected by the situation. A study of the functions of pig vocalizations in a human approach test suggested that squeals might result from a higher level of arousal than grunts (Marchant et al., 2001). Additionally, Weary and colleagues (1999) found that piglets in isolation at lower temperatures used more and higher frequency calls than litter-mates isolated in an enclosure kept at 30°C. Social isolation of 20- to 26-d-old piglets caused them to double their call rate when sow calls were played back (Weary et al., 1997), suggesting vocalizations to be a good indication of the degree of stress experienced by piglets. Increased rate of high frequency calls have also been described as a reliable indicator of pain in piglets during castration (White et al., 1995). Our study did not find differences in squeals (evaluated alone), but grunts and grunts and squeals together (vocalizations) were greater. The grunts may be interpreted as more exploratory than distress based on the frequency of the vocalization as an indicator of stress. These studies suggest that more frequent use of vocalizations may indicate exploration or urgency by piglets from stall-housed gilts.

Piglets from S gilts expressed more vocalizations during isolation testing as well as reduced weight gain at weaning, suggesting piglets from S gilts might have been exposed to prenatal stress. We speculate that this indicates stalls may be more stressful on pregnant gilts than the group system we provided. If stereotypic behavior caused the release of opioids to aid in coping, our results may be in agreement with previous studies finding morphological and behavioral changes induced

by prenatal stress, possibly resulting from excess opioid activity induced by maternal stress (Keshet and Weinstock, 1995).

We selected piglets that were midweight and thus less likely to be stressed by dominance or subordinance. Piglets from either the dominant or subordinant group may have a quite different profile and responses to maternal stressors. Similarly, the selection of only barrows narrowed our focus. Female piglets may have different behavioral and immunological responses to the maternal housing. The lack of differences observed in pregnant gilts and in immune competence of piglets may also be due to studying first parity gilts only. Subsequent research documenting multiparious sows will provide more information on possible chronic stressors inflicted by gestational housing. Also, differences in neonatal maternal care might have affected piglet responses. Different gestational housing systems may affect the way sows care for their piglets. Further experiments that cross-foster the piglets would allow discrimination of direct prenatal stress effects on the piglet compared with prenatal stress effects on the sow that are transmitted by behavior, pheromones, or by colostrum and milk.

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